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A REVIEW OF LABORATORY TESTS ON THE TOXICITY OF SOME N-SUBSTITUTED
BENZAMIDES TO VARIOUS INSECTS

By S. I. Gertler
Division of Insecticide Investigations

The Division of Insecticide Investigations prepared a number of N-substituted benzamides and submitted them to other Divisions of the Bureau for laboratory tests against various insects. Some of these compounds had some insecticidal value and others showed synergistic action. A patent on benzamides as synergists has been issued (4). N,N-Diethylbenzamide shows pronounced repellency against certain types of mosquitoes, and a patent on its use as a repellent has been granted (3). It was therefore considered advisable to compile the results of the tests in such a manner as to indicate the relative toxicity of the compounds to each insect.

All the compounds listed were prepared by the reaction of benzoyl chloride with an amine or amino compound under suitable conditions. In this class of N-substituted benzamides are included all compounds containing one or two benzoyl groups, chemically designated C_6H_5CO- . Most of the compounds are solids which can be ground up and used in suspension or admixed with various diluents as desired. Some of the compounds are colorless liquids, and only these were tested against flies and as mosquito repellents.

The insects tested and the Divisions in which they were tested are as follows:

Division of Cereal and Forage Insect Investigations:

European corn borer (Pyrausta nubilalis (Hbn.))

Division of Control Investigations:

Three-striped blister beetle (Epicauta lemniscata (F.))

Greenhouse leaf tier (Phlyctaenia rubigalis (Guen.)) (= P. ferrugalis (Hbn.))

Hawaiian beet webworm (Hymenia recurvalis (F.)) (= H. fascialis (Cram.))

House fly (Musca domestica (L.))

A looper (Pseudaplusia rufationis (Guen.)) (= Autographa oo (Stoll))

Melonworm (Diaphania hyalinata (L.))

Southern armyworm (Prodenia eridania (Cram.))

Southern beet webworm (Pachyzancla bipunctalis (F.))

Division of Fruit Insect Investigations:

Codling moth (Carpocapsa pomonella (L.))

Division of Insects Affecting Man and Animals:

Screw-worm (Callitroga americana (C. and P.)) (= Cochliomyia a.
C. and P.)

The methods used for testing are the usual standardized ones which have been used in the past, and so are mentioned only briefly. All the compounds tested against each insect are listed in order of toxicity. Compounds that were tested both as a dust and as a spray are listed twice. All dosages given are for dusts in terms of the pure compound. Where no figure is given in the dosage column, the material was applied as a spray. All sprays contained 8 pounds of the compound per 100 gallons of water unless indicated otherwise.

European Corn Borer

Newly hatched larvae were fed sprayed cauliflower leaves. In all tests the larvae were exposed for 2 days.

Compound	Percent kill
o-Benzaniside	95
1-Benzoyl-2-phenylhydrazine (4 lb.)	94
N,N-Diisopropylbenzamide	92
N-(1-Methylamyl)benzamide	92
2'-Nitrobenzanilide	66
3'-Nitrobenzanilide	57
o-Benzophenetide	50
2'-Chlorobenzanilide	39
N-sec-Butylbenzamide	32
1,4-Dibenzoylpiperazine	28
N-Isopropylbenzamide	25
3'-Chlorobenzanilide	19
N,N-Diisobutylbenzamide	19
N,N-Dibenzoyl-p-phenylenediamine	18
N,N-Dicyclohexylbenzamide	18
9-Benzoylcarbazole	17
4'-Ethoxybenzanilide	17
2'-Bromobenzanilide	16
4'-Nitrobenzanilide	15

European Corn Borer—(Continued)

Compound	Percent kill
p-Benzamidobenzoic acid, ethyl ester	10
1,2-Dibenzoylphenylhydrazine	7
N-Isobutylbenzamide	7
N-Propylbenzamide	7
2-Benzamidoanthraquinone	6
3'-Bromobenzanilide	6
N,N'-Dibenzoyl-m-phenylenediamine	4
2',5'-Dichlorobenzanilide	4
4'-Bromobenzanilide	3
4'-Chlorobenzanilide	3
N,N-Dibenzylbenzamide	3
N,N-Diphenylbenzamide	3
N-(2-Naphthyl)benzanilide	3
o-Phenylbenzanilide	3
p-Benzaniside	2
N-Hydroxymethylbenzamide (4 lb.)	2
Benzamide	1
N,N'-Dibenzoylmethanediamine (4 lb.)	1
N-Benzylbenzanilide	0
N-(1-Naphthyl)benzanilide	0

Three-Striped Blister Beetle

Adult beetles were fed Swiss chard leaves dusted with powdered pyrethrum flowers containing 10 percent of the compounds being tested. Other beetles were dusted with pyrethrum alone as the control. Any additional effect was assumed to be due to the compound. All exposures were for 2 days.

Compound	Dosage (micrograms per square centimeter)	Percent kill	
		Compound	Pyrethrum
N,N-Dibutylbenzamide	215	100	64
N-Butylbenzamide	200	92	4
N,N-Diisobutylbenzamide	130	83	4
N-Amylbenzamide	245	58	64

Greenhouse Leaf Tier

Fourth instars were fed dusted collard leaves.

Compound	Dosage (micrograms per square centimeter)	Days exposed	Percent kill
<u>o</u> -Benzanilide	155	3	37
<u>N</u> -(1-Methylamyl)benzamide	185	3	33
<u>o</u> -Benzophenetide	230	2	29

Hawaiian Beet Webworm

Fourth instars were fed dusted Swiss chard leaves. All materials were exposed for 2 days except the mixture with pyrethrum, which was exposed for 3 days.

Compound	Dosage (micrograms per square centimeter)	Percent kill
3'-Nitrobenzanilide	125	20
9-Benzoylcarbazole	170	15
<u>p</u> -Benzamidobenzoic acid, ethyl ester	110	14
N,N-Diisobutylbenzamide ^{1/}	230	14
<u>o</u> -Phenylbenzanilide	130	8
<u>N</u> -Propylbenzamide	170	8
1,2-Dibenzoyl-1-phenylhydrazine	155	4
N,N-Diphenylbenzamide	300	4
4'-Ethoxybenzanilide	215	4
N-(1-Naphthyl)benzanilide	130	4
2-Benzamidoanthraquinone	240	0
<u>p</u> -Benzanilide	310	0
N-Benzylbenzanilide	305	0
4'-Chlorobenzanilide	260	0
N,N'-Dibenzoyl- <u>m</u> -phenylenediamine	225	0
N,N'-Dibenzoyl- <u>p</u> -phenylenediamine	125	0
2',5'-Dichlorobenzanilide	125	0
N-(2-Naphthyl)benzanilide	320	0
2'-Nitrobenzanilide	285	0
4'-Nitrobenzanilide	195	0

^{1/} 10 percent of a 1:3 mixture of this compound and pyrophyllite plus 90 percent of pyrethrum.

House Fly (2)

The tests were made on adult house flies by the turntable method. All counts were made after 2 days. These tests were conducted to show any synergism which the compound might have. Two solutions were compared, one containing the compound alone dissolved in deodorized kerosene containing 10 percent of acetone, and the other the same solution containing in addition 0.5 mg. of pyrethrins per milliliter of solution. The standard pyrethrum solution containing 0.5 mg. of pyrethrins per milliliter gave 15-19 percent kill. Some compounds were tested at two concentrations.

Compound	Concentration, (percent)	Estimated 10-min. knock- down (percent)	Percent kill
With pyrethrum:			
N-Butylbenzamide	1.0	100	65
N-Amylbenzamide	1.0	100	53
N,N-Dibutylbenzamide	1.0	100	50
N,N-Diisobutylbenzamide	1.0	100	35
N-Isobutylbenzamide	1.0	100	31
N-Propylbenzamide	1.0	100	28
N,N-Diisobutylbenzamide	.2	100	26
N,N-Dipropylbenzamide	1.0	100	26
N,N-Di-(2-ethylhexyl)benzamide	1.0	100	25
N,N-Diethylbenzamide	1.0	100	22
N-Ethylbenzamide	1.0	100	19
N-Isobutylbenzamide	.2	100	17
N-Propylbenzamide	.2	100	17
Benzamide	1.0	100	16
N-Methylbenzamide	.2	100	16
N-Ethylbenzamide	.2	100	13
N-Methylbenzamide	.2	100	11
Without pyrethrum:			
N-Butylbenzamide	1.0	25	7
N,N-Dibutylbenzamide	1.0	5	5
Benzamide	1.0	10	3
N,N-Di-(2-ethylhexyl)benzamide	1.0	0	3
N-Isobutylbenzamide	.2	0	3
N-Ethylbenzamide	1.0	10	2
N-Isobutylbenzamide	1.0	0	2
N-Methylbenzamide	1.0	0	2
N-Amylbenzamide	1.0	50	1
N,N-Dibutylbenzamide	1.0	10	1
N,N-Diisobutylbenzamide	.2	10	1
	1.0	0	1
N,N-Dipropylbenzamide	1.0	10	1
N-Ethylbenzamide	.2	5	1
N-Methylbenzamide	.2	5	1
N-Propylbenzamide	.2	0	1
	1.0	10	1

Looper

Fourth instars were fed collard leaves dusted with a mixture containing 10 percent of a 1:3 mixture of the compound with pyrophyllite.

Compound	Dosage (micrograms per square centimeter)	Days exposed	Percent kill
N-Butylbenzamide	45	2	85
N,N-Dibutylbenzamide	40	3	85
N-Amylbenzamide	45	3	69
N,N-Diisobutylbenzamide	40	3	58
N-Isobutylbenzamide	35	3	47

Melonworm

Fourth and fifth instars were fed dusted or sprayed pumpkin leaves. Some of the compounds were tested in mixtures with pyrethrum.

Compound	Instar	Dosage (micrograms per square centimeter)	Days exposed	Percent kill
N-sec-Butylbenzamide	4	-	4	100
N,N-Diisobutylbenzamide ^{1/}	4	130	2	96
N,N-Diisopropylbenzamide	4	160	3	96
1-Benzoyl-2-phenylhydrazine ^{2/}	4	280	3	92
N,N-Dibutylbenzamide ^{1/}	4	215	2	91
N-Isobutylbenzamide ^{1/}	4	155	2	91
N-Butylbenzamide ^{1/}	4	200	2	87
N-Amylbenzamide ^{1/}	4	245	2	79
1-Benzoyl-2-phenylhydrazine	4	-	3	71
N-Hydroxymethylbenzamide	4	250	3	46
N-Amylbenzamide ^{2/}	4	240	3	33
N-Isobutylbenzamide ^{2/}	4	260	3	33
N-Isopropylbenzamide	4	190	3	33
N,N-Dibutylbenzamide ^{2/}	4	250	3	29

^{1/} 10 percent in pyrethrum.

^{2/} See footnote 1, page 4.

Melenworm--(Continued)

Compound	Instar	Dosage (micrograms per square centimeter)	Days exposed	Percent kill
N-Propylbenzamide	5	540	3	24
N,N'-Dibenzoylmethanediamine	4	255	3	21
N-Isopropylbenzamide	4	-	4	21
N-(1-Methylamyl)benzamide	4	185	3	16
N-Butylbenzamide ^{2/}	4	240	3	14
N-sec-Butylbenzamide	4	125	3	13
2'-Nitrobenzanilide	4	215	2	8
N,N-Diphenylbenzamide	4	270	2	5
Benzamide	5	260	2	4
o-Benzaniside	4	155	3	4
N,N-Diisobutylbenzamide	5	310	2	4
2-Benzamidoanthraquinone	4	265	2	0
p-Benzamidobenzoic acid, ethyl ester	4	185	2	0
p-Benzaniside	4	165	2	0
o-Benzophenotide	4	230	2	0
9-Benzoylcarbazole	4	150	2	0
N-Benzylbenzanilide	5	250	2	0
2'-Bromobenzanilide	5	280	2	0
3'-Bromobenzanilide	5	215	2	0
4'-Bromobenzanilide	5	140	2	0
2'-Chlorobenzanilide	5	250	2	0
3'-Chlorobenzanilide	5	230	2	0
4'-Chlorobenzanilide	5	250	2	0
N,N-Dibenzoyl-m-phenylene- diamine	4	270	2	0
N,N-Dibenzoyl-p-phenylene- diamine	4	80	2	0
1,2-Dibenzoyl-1-phenyl- hydrazine	5	200	2	0
1,4-Dibenzoylpiperazine	5	100	2	0
N,N-Dibenzylbenzamide	5	170	2	0
2',5'-Dichlorobenzanilide	5	140	2	0
N,N-Dicyclohexylbenzamide	5	100	2	0
4'-Ethoxybenzanilide	5	210	2	0
N-(1-Naphthyl)benzanilide	4	100	2	0
N-(2-Naphthyl)benzanilide	4	180	2	0
3'-Nitrobenzanilide	4	205	2	0
4'-Nitrobenzanilide	4	155	2	0
o-Phenylbenzanilide	4	180	2	0

^{2/} See footnote 1, page 4.

Southern Armyworm

Insects were fed dusted or sprayed collard leaves.

Compound	Instar	Dosage (microgram per square centimeter)	Days exposed	Percent kill
1-Benzoyl-2-phenylhydrazine ^{1/}	4	400	2	100
N-Isopropylbenzamide	4	-	6	87
o-Benzaniside	4	153	3	58
N-Isopropylbenzamide	4	190	3	58
N-(1-Methylamyl)benzamide	4	185	3	50
N,N-Dibutylbenzamide ^{2/}	3	215	2	46
N,N-Diisopropylbenzamide	4	160	3	46
N,N-Dibutylbenzamide ^{2/}	3	215	2	46
N-Amylbenzamide ^{2/}	3	245	2	37
1-Benzoyl-2-phenylhydrazine ^{1/}	4	-	3	25
N-Hydroxymethylbenzamide	4	230	3	18
o-Benzophenetide	4	230	2	16
N,N'-Dibenzoylmethanediamine	4	230	3	14
N-Isobutylbenzamide ^{2/}	3	155	2	12
N-sec-Butylbenzamide	4	125	3	8
p-Benzaniside	4	165	2	4
2'-Chlorobenzanilide	4	300	2	4
N,N'-Dibenzoyl-p-phenylenediamine	4	80	2	4
N,N-Diisopropylbenzamide	4	-	2	4
2-Benzamidoanthraquinone	4	265	2	0
Benzamidobenzoic acid, ethyl ester	4	185	2	0
Benzamide	4	325	2	0
9-Benzoylcarbazole	4	150	2	0
N-Benzylbenzanilide	5	250	2	0
2'-Bromobenzanilide	4	180	2	0
3'-Bromobenzanilide	4	290	2	0
4'-Bromobenzanilide	4	135	2	0
N-Butylbenzamide ^{2/}	3	200	2	0
3'-Chlorobenzanilide	4	170	2	0
4'-Chlorobenzanilide	4	230	2	0
N,N'Dibenzoyl-m-phenylenediamine	4	270	2	0
1,2-Dibenzoyl-1-phenylhydrazine	5	200	2	0

^{1/} 1:3 dust in pyrophyllite.

^{2/} See footnote 1, page 6.

Southern Armyworm--(Continued)

Compound	Instar	Dosage (micrograms per square centimeter)	Days exposed	Percent kill
1,4-Dibenzoylpiperazine	4	85	2	0
N,N-Dibenzylbenzamide	4	180	2	0
2',5'-Dichlorobenzanilide	5	140	2	0
N,N-Dicyclohexylbenzamide	4	150	2	0
N,N-Diisobutylbenzamide	4	310	2	0
N,N-Diisobutylbenzamide ^{2/}	3	310	2	0
N,N-Diphenylbenzamide	4	270	2	0
4'-Methoxybenzanilide	5	210	2	0
N-(1-Naphthyl)benzanilide	4	100	2	0
N-(2-Naphthyl)benzanilide	4	180	2	0
2'-Nitrobenzanilide	4	215	2	0
3'-Nitrobenzanilide	4	205	2	0
4'-Nitrobenzanilide	4	155	2	0
o-Phenylbenzanilide	4	180	2	0
N-Propylbenzanilide	4	435	2	0

^{2/} See footnote 1, page 6.

Southern Beet Webworm

Fourth instars were fed dusted pigweed leaves and exposed for 3 days.

Compound	Dosage (micrograms per square centimeter)	Percent kill
1-Benzoyl-2-phenylhydrazine ^{1/}	250	87
1-Benzoyl-2-phenylhydrazine ^{1/}	-	54
N-Hydroxymethylbenzamide	230	11
N,N'-Dibenzylmethanediamine	270	9

^{1/} See footnote 1, page 8

Codling Moth (5)

These tests were conducted by the apple-plug method on newly hatched larvae, each plug being infested shortly after application. Each compound was sprayed at a concentration of 4 pounds per 100 gallons.

Codling Moth

Compound	Percent of wormy apple plugs	Percent of apple plugs stung
1-Benzoyl-2-phenylhydrazine	68	2
1,4-Dibenzoylpiperazine	76	0
N-Hydroxymethylbenzamide	79	16
N,N'-Dibenzoyl-p-phenylenediamine	82	0
N,N'-Dibenzoylmethanediamine	83	1
2',5'-Dichlorobenzanilide	85	0
N-(1-Naphthyl)benzanilide	85	5
9-Benzoylcarbazole	88	0
3'-Nitrobenzanilide	89	0
1,2-Dibenzoyl-1-phenylhydrazine	91	0
N,N-Diphenylbenzamide	91	0
2'-Nitrobenzanilide	91	0
p-Benzaniside	92	4
3'-Bromobenzanilide	92	0
N-Propylbenzamide	92	4
p-Benzamidobenzoic acid, ethyl ester	93	0
N-sec-Butylbenzamide	93	0
4'-Chlorobenzanilide	93	0
N-Isopropylbenzamide	93	0
o-Phenylbenzanilide	93	0
N-Benzylbenzanilide	94	0
2'-Bromobenzanilide	94	0
4'-Ethoxybenzanilide	94	0
N,N-Dicyclohexylbenzamide	95	0
2-Benzamidoanthraquinone	96	0
4'-Bromobenzanilide	96	0
2'-Chlorobenzanilide	96	0
4'-Nitrobenzanilide	96	0
o-Benzophenetide	97	0
N,N-Diisopropylbenzamide	97	0
N-Isobutylbenzamide	97	0
o-Benzaniside	98	0
3'-Chlorobenzanilide	98	0
N,N'-Dibenzoyl-m-phenylenediamine	99	0
N,N-Dibenzylbenzamide	99	0
N,N-Diisobutylbenzamide	99	0
N-(1-Methylamyl)benzamide	99	0
N-(2-Naphthyl)benzanilide	99	0
Benzamide	100	0

Screw-Worm

The jar method (1) was used on newly hatched larvae.

Compound	Minimum lethal concentration (percent)
N- <u>sec</u> -Butylbenzamide	0.05-0.10
N-Isopropylbenzamide	
1-Benzoyl-2-phenylhydrazine	.10-.17
N,N-Diisopropylbenzamide	
Benzamide	.17-.67
N-Hydroxymethylbenzamide	
N-Isobutylbenzamide	
N-Propylbenzamide	Slightly toxic at .67
<u>o</u> -Benzaniside	

The following compounds were nontoxic at a concentration of 0.67 percent;

2-Benzamidoanthraquinone
p-Benzamidobenzoic acid, ethyl ester
p-Benzaniside
o-Benzophenetide
9-Benzoylcarbazole
N-Benzylbenzanilide
2'-Bromobenzanilide
3'-Bromobenzanilide
4'-Bromobenzanilide
2'-Chlorebenzanilide
3'-Chlorebenzanilide
4'-Chlorebenzanilide
N,N-Dibenzoylmethanediamine
N,N'-Dibenzoyl-m-phenylenediamine
N,N'-Dibenzoyl-p-phenylenediamine

1,2-Dibenzoyl-1-phenylhydrazine
1,4-Dibenzoylpiperazine
N,N-Dibenzylbenzamide
2',5'-Dichlorebenzanilide
N,N-Dicyclohexylbenzamide
N,N-Diphenylbenzamide
4'-Ethoxybenzanilide
N-(1-Methylamyl)benzamide
N-(1-Naphthyl)benzanilide
N-(2-Naphthyl)benzanilide
2'-Nitrobenzanilide
3'-Nitrobenzanilide
4'-Nitrobenzanilide
o-Phenylbenzanilide

Summary of Results

A compound was considered toxic to leaf-eating insects if it gave at least a 75-percent kill, and to screw-worms if the minimum lethal concentration was 0.1 percent. On this basis the following N-substituted benzamides were found to be toxic to one or more insects (the number of species to which each was toxic is indicated in parenthesis): 1-Benzoyl-2-phenylhydrazine (5), N,N-diisopropylbenzamide (3), N-butylbenzamide (2), N-sec-butylbenzamide (2), N,N-dibutylbenzamide (2), N-isopropylbenzamide (2), N-amylbenzamide (1), o-benzaniside (1), N,N-diisobutylbenzamide (1), N-isobutylbenzamide (1), and 1-(1-methylamyl)benzamide (1).

A compound was considered to have a synergistic effect on pyrethrum if at least 50 percent mortality was obtained when a 1-percent solution was added to a pyrethrum solution containing 0.5 mg. of pyrethrins per milliliter.

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